

### Clinical guidelines for traumatic brain injuries in children and boys

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#### **Abstract**

The main aim of management of pediatric traumatic brain injury (TBI) is to hold normal ranges for optimizing the most proper outcomes. However, to provide physiologic requirements to an injured brain it is very important to enhance the quality of recovery and minimize secondary injuries. The aim of study is to identify proper guidelines to manage pediatric TBI. A comprehensive research was conducted on biomedical and pharmacologic bibliographic databases of life sciences, i.e., PubMed, EMBASE, MEDLINE, LILACS database, global independent network of Cochrane, Science Direct and global health library of Global Index Medicus (GIM) from 2000 to 2019. Main objective of this study was to provide a comprehensive review of available clinical practice guidelines for TBI. These guidelines can be administered to a pediatric population to improve the quality of clinical practice for TBI. These guidelines could be applied worldwide, despite different traditional demographic and geographic boundaries, which could affect pediatric populations in various ranges of ages. Accordingly, advances in civil foundations and reforms of health policies may decrease pediatric TBI socioeconomic burdens.

**Key Words:** Pediatric, traumatic brain injury, TBI management, clinical guidelines.

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One of the main causes of disability and death among children is traumatic brain injury (TBI). A wide range of traumatic injuries to the layers of scalp, the bony structure of skull and the brain may result from TBI. These kinds of injuries are not the same as those in adults in both pathophysiology and managements.<sup>1</sup> These dissimilarities are because of structural changes related to age, injury mechanisms related to child physical ability and the difficulty of neurological assessment in pediatric populations. The scalp consists of five layers, which have large number of blood vessels. Thus, it could be one of the main causes of fatal blood loss when injured. Furthermore, even small amount of blood loss in a baby, toddler and small child that happen without any evident external bleeding, could cause hemorrhagic shock.<sup>2</sup> Anyway, in children these kinds of injuries may induce special pathological response to injured brain with specific physical symptoms of neurological problems.

Progression of medical imaging techniques enhanced health care quality by helping healthcare providers in assessment and identification of children with TBI. Specifically, magnetic resonance imaging (MRI) special facilities improved diagnostic accuracy, and thus proper treatment selection, preventing of adverse side effects like post-traumatic seizures and other brain dysfunctions.<sup>3</sup> The incidence rate of pediatric TBI is not equal in various geographical areas, being significantly higher in low-income countries. In accordance with the global statistics, more than 90% of injuries among pediatric population happens in low and middle income countries, ninety percent of these injuries being inadvertent.<sup>4</sup> The main causes of pediatric TBI in low and middle income countries are motor-vehicle crashes due to large development of unsafe transportation systems and motorization.<sup>5</sup> Consequently, the vulnerability of children against traumatic injuries and especially TBIs is

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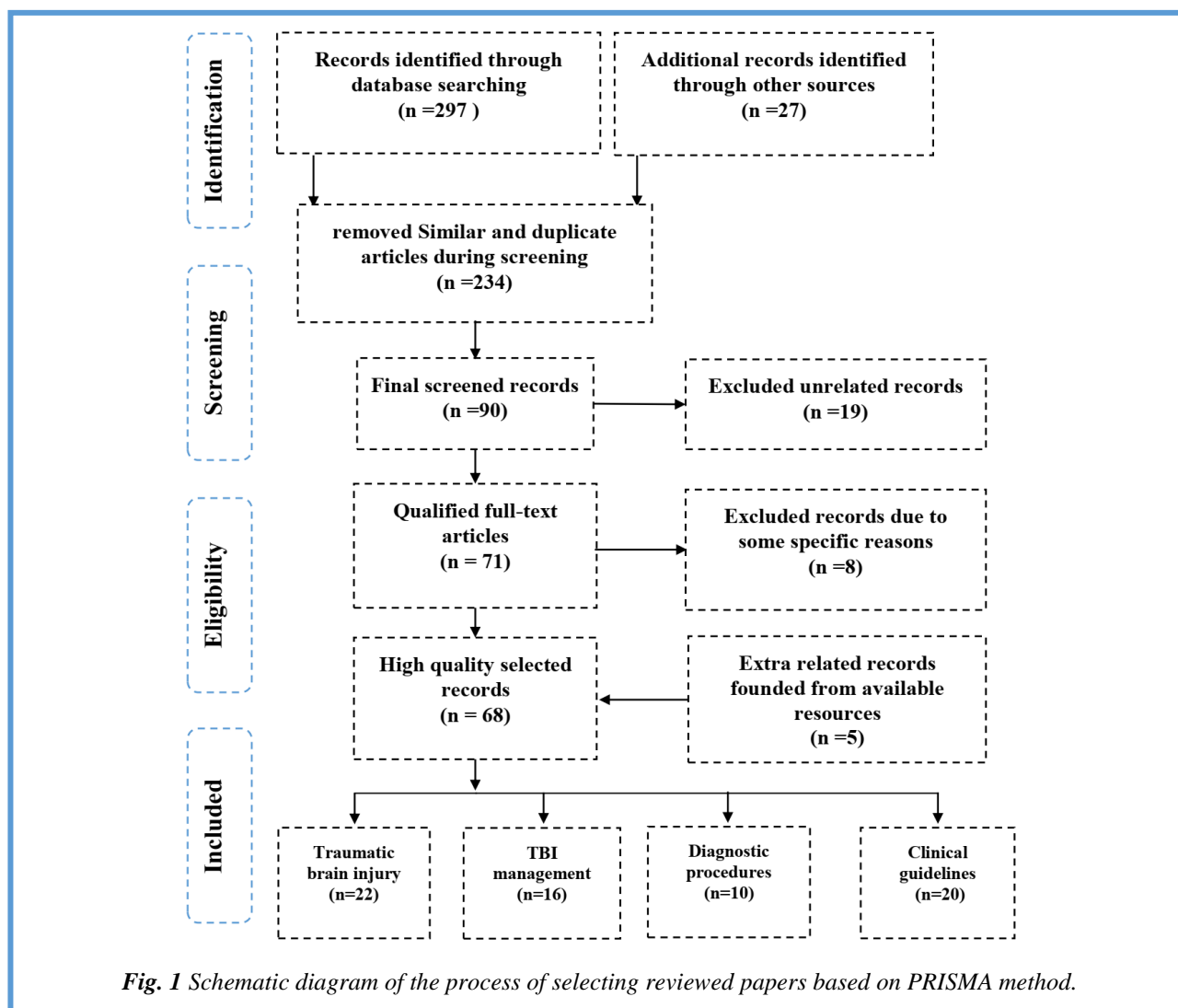


Fig. 1 Schematic diagram of the process of selecting reviewed papers based on PRISMA method.

higher than other populations. Additionally, the TBI consequences would developed to serious disability with related financial and emotional large costs.<sup>6</sup>

Clinical practice guidelines of have an essential role to improve the outcomes of TBI management among low and middle-income populations, through care progression, initiatives of injury prevention, precise rehabilitation services and strong organized trauma systems.<sup>7</sup> Performance of advanced medical guidelines of TBI among adults seems to be main causes of decrement of fatality rate in case of hospital care.<sup>8</sup> In addition, some other studies have shown that the clinical outcomes of TBI management could be improved by following up and administering the guidelines of Brain Trauma Foundation (BTF) within adult as well as pediatric populations.<sup>9,10</sup> Anyway, applying the most proper clinical practice guidelines for acute TBI management in low and middle-income countries is a big challenge. In this regard, one of the main restrictions is lack of proper access to resources for preparing proper guidelines on TBI. On the other hand, the existing gaps among the resources and the essential capacity of related

resources in addition with the trauma systems variability often could not be covered easily.<sup>11,12</sup> Initial management of the acute airway as well as prescribing most appropriate sedative agents, the most suitable ventilation and also the potent strategies of hyperosmolar therapy were picked out mainly for preserving normal cerebral perfusion pressure (CPP). Anyway, some novel and effective clinical practice guidelines for serious management of pediatric TBI should be created. Additionally, creating some specific guidelines mainly for pediatric population could be the main capability of improving the quality of clinical practice guidelines of TBI. The main objective of this study is to evaluate the existing clinical practice guidelines quality for proper diagnosis and management of pediatric TBI.<sup>13</sup>

## Materials and Methods

To achieve the objectives of this study, the candidate articles in terms of evidence-based medicine (EBM), traumatic brain injury (TBI), traumatic injuries involving the intracranial, scalp and skull structures and clinical practice guidelines were identified. Figure 1 shows the

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schematic diagram of article selection procedure designed according to the PRISMA method.

A comprehensive search was conducted on biomedical and pharmacological bibliographic database of life sciences, such as PubMed, EMBASE, MEDLINE, LILACS database, global independent network of Cochrane, Science Direct and global health library of Global Index Medicus (GIM). By referencing these databases, a universal literature review was carried out through combining various recent studies in terms of pediatric traumatic brain injury, epidemiology, management and related clinical guidelines in accordance with various related articles published from 2000 to 2019 that could cover this area of recommendations. Totally 324 articles were checked

briefly which about 117 of them were deleted due to less related content to the objective of the study. Finally, after deleting some other articles with subjective weakness and adding some other articles through additional databases, 68 articles were chosen.

### Results

#### *TBI epidemiology*

Among all kinds of traumatic injuries, damages of brain are the major that could cause permanent disability or death. In accordance with Centers for Disease Control and Prevention (CDC)<sup>14</sup> any year 475,000 U.S. persons with an age lower than 14 years undergo TBI. About ninety percent of them return to their home after a mild intercession safely, but seven percent would be

**Table 1.** The scores of Pediatric Glasgow Coma Score (PGCS)<sup>20</sup>

Age Group		Less than 23 months	2 to 5 years	Over 5 years
	Score			
Best verbal response	1	No response	No response	No response
	2	Grunts	Grunts	Unclear sounds
	3	Screaming or/and crying at inappropriate times	Screams or/and cries	Inconvenient phrases or words
	4	Load cries	Inconvenient phrases or words	Disoriented and converses
	5	Appropriate smile and coo	Appropriate phrases and words	Oriented and converses
Age group				
	The score	Less than one year	Over one year	
Eye opening	1	No response	No response	
	2	To pain	To pain	
	3	To shout	To verbal command	
	4	Spontaneously	Spontaneously	
Best motor response	1	No response	No response	
	2	Abnormal deployment	Abnormal deployment	
	3	Abnormal posturing	Abnormal posturing	
	4	Withdrawal reflex	Withdrawal reflex	
	5	Localizes to pain	Localizes to pain	
	6	Involuntary movements	Obeys	

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hospitalized and three percent die due to severity of injuries. The emergency visits at the emergency medicine departments in children younger than four years are more common than in other age groups. Only a low rate of them would be hospitalized because of their severe conditions. It should be noted that, the death rate among younger children who have BTI is more common than among older.<sup>14</sup> Based on available literature the potential of being hurt with traumatic brain injuries among boys is higher than among girls.<sup>15</sup> The age is one of the factors that could affect main mechanisms of TBI among pediatric populations. As an instance, the accidental falling would be the main causes of TBI among pediatric population at the age group of 0-14 years.<sup>16</sup> In children who are at age group of 0-4 years the main causes of being injured is not just falling from a height but also due to motor vehicle accidents. It's while in children within the age group of 4-8 years would be injured not only due to motor vehicle accidents and

falling from heights but it would be happening because of other transportation injuries like bicycle incidents. Pediatric abusive head trauma (AHT) could be seen among population of age group of 0-2 years more than other age groups. Among these injured young infants about 0.03% would be hospitalized.<sup>17,18</sup>

### Specifying characteristics of injury

Based on age and progression the clinical presentation of children with TBI are not fixed and would change with the trauma severity. According to analyzed reviews, the Pediatric Glasgow Coma Score (PGCS) is generally used to evaluate consciousness level and to define severity of the head injuries (Table 1).<sup>19</sup> In general, focal neurologic signs would appeared at the injury time that would be considered as indicators of further advancement of pathological changes. The changes gradually occur in accordance with anatomy and age-specific characteristics of face, brain, neck and skull. These make children very

**Table 2. : Properties of injuries based on age and progression. Derived from Takashi A, et al.(2017)<sup>22</sup>**

Age Group	Newborns	Infants		Toddlers And School children		Adolescents	
Head trauma during delivery	Caused by traction and compression of head through vaginal delivery by means of instruments used in obstetrics procedures	Head injury caused through accident	Induced due to unsuitable child care practices	Head injury caused through accident	The rate of accidents will increase as a consequence of progression of motor riding ability of children	Motorcycle and bike accidents	The prevention knowledge should be enhanced
Intracerebral hemorrhage		Pediatric abusive head trauma (AHT)					
Cephalohematoma					The rate of traffic-related pedestrian injuries is high in this age group		
Subgaleal hemorrhage	Abnormally low level of oxygen in the blood and lower weight during the birth procedure are risk factors for intracerebral hemorrhage						

sensitive to injuries that do not happen in adults (Table 2). The children brain structure is a combination of high plasticity and deformity that has peculiar biomechanical characteristics, very relevant for pediatric TBI. Consequently, in children the absorption of external forces is higher in comparison to adults. The rigidity of infant skull is minimal, so the open sutures would act as joints, which could cause a slight degree of movement as response to mechanical stress.<sup>21,22</sup> Anyway, even during normal delivery intra and extracranial injuries would happen. On the other hand, intracerebral hemorrhage could happen during vaginal deliveries due to traction and compression applied on the fetal head when passing the birth canal, in particular if obstetric instruments are applied. Further, infants are prone to fall into situations like subgaleal hemorrhage and cephalohematoma.<sup>23</sup> Within this age group, the abnormal condition of hypoxemia and low birth weight are possible risk factors for intraventricular bleeding. However, these risk factors must be distinguished from bleeding disorder and pediatric abusive head trauma (PAHT). Uncontrollable shaking during delivery could cause small deformation within the skull. On the other hand, the high plastic property of the skull would result in share of forces amongst the adjacent cortical tissue and vessels, the skull and brain. The forces that are shared would cause vessels to bear sharing and stretching injuries and the functional tissue in the brain bear parenchyma.<sup>24</sup> Compared with their body size, the size of children head is larger than in adults. For this reasons, the possibility of head being impacted in pediatric TBI is higher in comparison with adults. However, the relation among the size of body and head will continuously decrease following the age increasing. Additionally, because the weight of head in comparison with other body parts is high, the head vulnerable potential to TBI is higher which could cause various the external forces. The distribution of the existing white matter within the deeper tissues of the brain, which have a layer of myelin with, is not the same among newborns and adults.<sup>25</sup> The brain of newborn contains large amount of water, but a myelinated brain is denser according to advancement of myelination process. During the procedure of age progression, various areas of the brain would have different amount of myelination. It should be noted that, the process of myelination within these areas follows up an organized pattern with posterior-anterior and caudocranial predominance. The rate of traumatic forces absorption based on myelination degree will be various, somehow the TBI susceptibility would be increased in regions where there are unmyelinated areas.<sup>26</sup> The potential of sinuses in absorption of higher amounts of energy during the progression process would be higher; hence, less amount of direct energy would be exerted to the brain and skull. Consequently, along with the development of the face and gradual progression of paranasal sinus, the exerted damages would be restricted. The medical condition of frontal bossing among younger children could cause the

increment of the force, which would directly exerted to the frontal bone of the skull and underlying brain parenchyma. On other hand, along with increasing age, the progression of facial growth in both downward and forward directions, would cause the increment of the possibility of fractures of midface.<sup>27</sup>

### *TBI Clinical Characteristics and Diagnosis*

Novel researches have recommended that precise diagnosis, acute management and appropriate rehabilitation should be considered within an overall guideline for applying a more proper management procedure of TBI.<sup>28</sup> In this regard, the most possible components of TBI must be specified which include; acute traumatic intraparenchymal hemorrhage (IPH), extraparenchymal vascular injuries and vascular injuries. However, intraparenchymal hemorrhage (IPH) include intracerebral hemorrhage (ICH), the brain diffuses axonal injury (DAI) and intraventricular bleeding. Extraparenchymal vascular injuries are including traumatic blood accumulation of epidural hematoma (EDH), subdural hematoma (SDH), intraventricular bleeding and subarachnoid hemorrhage (SAH). On the other hand, vascular injuries are including false aneurysm, dural arteriovenous fistula (dAVF), carotid-cavernous sinus fistula (CCF) and vascular dissection.<sup>29</sup>

### *Guidelines on management of airway in TBI patients*

Based on the neurological scale of GCS the process of quick tracheal intubation in an unconscious pediatric TBI patient is recommended for proper control of airway, sufficient management of increased intracranial pressure (ICP), could barricade hypoxemia as a significant cause of secondary brain injury.<sup>30</sup> As guided, along with proper management of airway appropriate sedative or analgesic agents should be applied. In this regard, for achieving the most effective intervention of airway, the appropriate selection of sedative agents with sufficient dosage is recommended too. It should be noted that, preserving both pressures of cerebral perfusion and mean arterial is recommended to be considered as the major vital factors.<sup>30,31</sup> One group of these agents that could be applied adequately are benzodiazepines which proven to be beneficial due to their antiepileptic, amnesic and anxiolytic characteristics. On the other hand, respiratory depression as one of the main side effects should be prevented. Additionally, the sedation process would be prolonged from a metabolites development.<sup>31,32</sup>

### *The strategies of ventilation in TBI patients*

For minimizing or/and prevention of secondary brain injury after conducting an optimized sedation and providing a secure airway, preparing an impressive ventilation is demanded. Because the application of hyperventilation could cause cerebral vasoconstriction syndrome, decrease cerebral blood flow and brain oxygenation, it would induce cerebral ischemia. Consequently, in children with TBI, the application of hyperventilation is not recommended at all.<sup>33</sup> Cerebral

ischemia is proportionally associated with the extent of hyperventilation. It should be noted that, among pediatric TBI, a high rate of severe hypocapnia is related to high rate of mortality.<sup>34</sup> To consider hyperventilation for patients with persistent intracranial hypertension, brain ischemia must be preempted and progressive intraoperative neurophysiological monitoring should be initiated.<sup>35</sup> The main reason for conducting conservative care procedures of ventilation is the increased risks of lung injury. However, the main objectives of conducting proper ventilation in management of pediatric TBI are to prevent hypocapnia and hypoxia.<sup>36</sup>

### *Primary brain injury*

#### The fracture of skull

The procedure of management of fractures of skull among children should be carried out more cautiously. The fractures of frontal bone should be managed more critically and need immediate repair. However, the TBI cases, which contain fractures, would possibly include more than two bones. The potential bone, which mostly would involve in linear skull fractures, is including temporal, frontal, occipital and mainly parietal bone.<sup>37</sup> These kinds of fractures could be specified by the presence of ordinary sutures through their special anatomical configuration, existence of complex serrations and ossification signs beside available sutures. One the main clinical characteristics which could be applied indirectly in diagnostic procedure, is extracranial hypodermic edema. Additionally, one of the most effective imaging techniques that could be used for diagnosis of linear skull fractures among children is computed tomography (CT) scan with a high sensitivity rate in children under two years. However, this precise technique could specify brain lesions in about 25% of cases accurately.<sup>38</sup> Based on the approved novel guidelines in pediatric TBI who are not detected with non-displaced parietal linear skull fracture hospitalization is not required. It's while, in patients who have been detected with further injuries, abusive head trauma or alteration in mental status, hospitalization would be needed.<sup>39</sup> The simple type of skull fracture which could be induced from concentrate external forces is the most common in children amongst depressed skull fractures. The most common type of fractures among children under one year are compound fractures, which accounts for about ten percent of all fractures. In situation when fractures be observed over cerebral sinuses, for controlling and prevention of happening posttraumatic dural venous sinus thrombosis and progressive epidural hematoma (PEDH), children should be carried to the intensive care unit (ICU). The available guidelines for proper management of surgical procedure of TBI are based on some recommendation on surgical treatment, which could be conducted in the following situations:<sup>40,41</sup>

- I: The presence of cerebrospinal fluid (CSF) be detected obviously
- II: The presence of foreign body be detected clearly

- III: The medical removal of damaged or dead local tissue is required immediately
- IV: The localized wound is infectious
- V: The process of hematoma emptying is needed
- VI: When cosmetic surgery is needed

One of the main independent risk factors for occurrence of seizures that would be induced due to TBI is depressed fracture of the skull. It's while in accordance with recent guidelines, the association of these two mentioned factors could not be potentially be existing.<sup>42</sup> On the other hand, based on available guidelines in situations when depressed skull fractures which overlaid on the superior longitudinal sinus happened, enhancing the quality of venous blood circulation could significantly improve the function of nervous system.<sup>43</sup> The fracture of basal skull would be seen in children hardly ever. In children whose facial skeleton are not developed completely yet, happening basal skull fracture (BSF) at any rates could cause blood vessels and cranial nerve injuries.<sup>44</sup> These kinds of fractures would be presented as pediatric bacterial meningitis. However, in accordance with approved guidelines precise assessment of clinical symptoms and signs is necessary approximately in all cases. Within their study Alhelali et al.<sup>45</sup> by investigating the association of BSFs and mortality in pediatric TBI demonstrated that these kinds of fractures could be happening in about a quarter of patients. Another potential kind of fractures, which would be happen, is the fracture of temporal bone, which could be seen in about 33% of the patients.<sup>45</sup>

#### Craniocerebral erosion

Craniocerebral erosion is a kind of skull fractures, which could grow and usually could be happen because of the ordinary progression of cystic masses, which are filled with cerebrospinal fluid. This kind of fracture is a rare head injury complication that commonly comes with the parietal bone linear fractures in children younger than 36 months. In growing newborns, infants or children under 36 months, the growing skull fractures or cerebral herniation could magnify the line of fracture through the thick membrane of Dura.

These fractures happen because of pulsatile pressure through lesions, which are inherited, to the skull inner table, which would simplify nutritional deficiencies along the edges of the bone.<sup>46</sup>

Within the majority of cases, some cosmetic signs like pulsatile edema or/and skull depression could be considered as diagnostic factors. It's while some brain problems like seizures and headache would be presented just in few cases. Based on standardized guidelines in surgical treatment of cranioplasty computed tomography image reconstruction could be very effective. Proper comprehension of the pathology of lesions by application of specialized techniques of radiography is recommended to be used for more radical treatment of growing skull fracture (GSF).<sup>47</sup>

#### *Traumatic brain injury (TBI)*

### Epidural hematoma (EDH)

Due to the fact that, thick membrane of Dura mater among newborn is stuck to the skull inner surface strongly, traumatic epidural hematoma is not very common. Due to the fact that, the middle meningeal artery in newborn children does not exist in the skull and the atrioventricular groove initiated from external common carotid artery is not too deep, its potential in being damaged within TBI is high.<sup>48</sup> On the other hand, acute epidural hematoma in newborns is essentially venous and frequently would be generated through injuries which lie on top of the emissary veins rupture or/and the Dural venous sinuses within the fracture vicinity. In acute epidural hematoma situations, the small space of posterior fossa in the skull is frequently correlated with traumatic occipital condyle fractures which lie on top of the related region from the lateral to the s-shaped hollow curve of pars sigmoid.<sup>49</sup> The potential of happening arterial acute epidural hematoma which could be swiftly developed and cause a brain herniation and death, must be taken into account seriously. The occurrence of acute epidural hematoma in newborn children would happen mostly within the posterior fossa skull space exactly the same as brain Injury induced from Birth. In general, the acute epidural hematoma does not overpass the line of the suture. On the other hand, in situations when the solid edema of solidified blood induced from pediatric cerebral venous sinus could develop to outside or to the reverse side, so applying intensive care medicine may be needed.<sup>50,51</sup>

### Pediatric AHT

The occurrence rate of pediatric abusive head trauma among children whose age is lower than 12 months is about 0.05%. Formerly, based on the available guidelines pediatric AHT was known as shaken Baby Syndrome or inflicted traumatic brain injury. Abusive head trauma is a kind of head trauma, which is incorporating brain parenchyma, spinal cord injury and head injuries. The main mechanism of injury in abusive head trauma could be due to secondary brain injury because of hypotension or/and low oxygen within the body tissues and direct impact or/and vibrate or a mixture of them.<sup>52</sup>

One of the main causes of happening pediatric TBI in population under 24 months is abusive head trauma. Consequently, the consideration of abusive head trauma in diagnostic procedure of children with traumatic injuries is very vital. In this regard, clinical characteristics of abusive head trauma are such as nausea, seizures, decrement of consciousness and delayed milestone. Through applying diagnostic imaging techniques, in about 80% of cases, the most frequent finding is traumatic subdural hematoma (TSDH).<sup>53, 54</sup>

Some other properties of findings of applied imaging techniques are such as cerebral contusion, intracerebral hemorrhage and the presence of blood within the subarachnoid space. It is while traumatic subdural hematoma is not correlated with abusive head trauma at

all. On the other hand, the symptoms of seizures could be seen often in abusive head trauma. Additionally, as proved, traumatic scalp injuries, any kind of break in the skull bone and long bone fractures does not have a crucial connection with abusive head trauma.<sup>55</sup>

### Secondary traumatic brain injury

One other significant complications of TBI which is potentially fatal and frequently could be observed in computed tomography scans among pediatric abusive head trauma is cerebral edema. Due to the lack of CSF in cerebral edema patients, the findings of CT scan would be prepared more swiftly among children. Based on their findings, a quite benign course of the disease among children could be observed in comparison with adults.<sup>56</sup> Because of the presence of the developing mechanism of biological process of autoregulatory for supplying the blood to the brain, the vulnerability of children to hyperemia in the cerebral circulation is higher than adults, which could cause acute intracranial hypertension.<sup>57</sup> On the other hand, due to the fact that, mean blood pressure of infants is not too high and their blood reserve capacity is not high enough for compensating hypoxia and low blood pressure, any decrement in the blood supply to their brain would be justified.<sup>58</sup>

### Final recommendations on pediatric TBI management

As mentioned before, for achieving the most sufficient outcomes in management of TBI, a proper diagnostic method should be available. One of the main existing scientifically proven invasive techniques for proper monitoring of the pressure inside the skull is using the sensor of intraparenchymal hemorrhage which could be applied in children for detection of traumatic brain injury.<sup>59</sup> As instance, within their study Alkhoury et al.<sup>60</sup> reported that the application of this monitoring method could significantly decrease the mortality rate among children with TBI.<sup>53,54</sup> The overall effect of cerebral blood flow to the brain and the blood pressure inside the skull on TBI outcomes among adults is appropriately known. It's while, there is not any comprehensive studies on determining the perfusion pressure of the brain among children. So more precise investigation is recommended to be conducted in this regard.<sup>60</sup> The overall evaluation of potent guidelines for proper management of TBI among various age group of children population were conducted based on the final qualitative articles which selected for precise review. Obtained data from various areas showed that in any countries based on their economic condition some guidelines are available that are not the same in low, middle and higher income countries. Anyway, the main objective of creating a comprehensive guideline for pediatric traumatic brain injury is due to the fact that this complication is very dangerous and fatal.<sup>61</sup> The main focus of studies is on initial management, potential rehabilitation, ICU care,

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subsequent assessments, and the concussion setting evaluation, prehospital care broad spectrum, specialist care and neurosurgical unit care. The initial step at a situation when a pediatric TBI patient visits an emergency medicine department is to determine the severity level of injury through a precise diagnostic procedure. In this regard, for more accurate management of TBI it should be noted that, a more precise diagnosis procedure is demanded which must be conducted in any clinical procedures. One of the main diagnostic procedure, which could be applied, is using imaging techniques in the acute setting.<sup>33,62,63</sup> Long term guidelines for proper management of pediatric TBI and achieving both intellectual and physical outcomes are recommended to be administered. In this regard, some researchers have proposed an inclusive guiding protocol of multidisciplinary rehabilitation for facilitating and improving the capability of patients to back home or their common daily activities.<sup>64</sup> One other significant

guidance's which is recommended is to set the most proper communication amongst educators, specialists of rehabilitation unit, children and family members. Conducting these kind of cooperation's would provide a more obvious recognition of children functional capabilities and also enhance the possible immediate and reliable long-term outcomes among children.<sup>65</sup> Brain imaging techniques has a very significant role in the management process of pediatric TBI. The novel magnetic resonance imaging (MRI) modalities like nuclear magnetic resonance (NMR) spectroscopy, susceptibility weighted imaging (SWI), diffusion MRI, diffusion-weighted imaging (DWI) could provide more precise identification of various parameters which would specify improper function of neurological trauma and brain.<sup>66</sup> On the other hand, these techniques could provide more swift diagnosis of acute or chronic pediatric TBI among the specified population, so administration of various rehabilitation services would be conducted more

**Table 3. Recommendations for management of pediatric TBI. Derived from Sung A, et al. (2018)<sup>75</sup>**

Scopes of pediatric TBI management							
Sedative choice	Hyperventilation to be applied	Hyperosmolar agents effectiveness	Control of body temperature	Diabetes management	Neuroimaging indications	Monitoring pressure inside the skull	Preventive anticonvulsant
Clinical considerations							
The average blood pressure should be preserved during the tracheal intubation and any other invasive procedures	Hyperventilation could cause cerebral infarction or/and ischemic stroke	The solution of 3% hypertonic saline would decrease the requirement for attendant interventions for treatment of inappropriate pressure inside the skull	Hypothermia condition would cause heart arrhythmia and higher mortality rate	Higher levels of blood glucose could cause adverse side effects	Pediatric emergency care applied research network (PECARN) proposes to immediately monitor children based on glasgow coma scale	-	Whenever post-traumatic seizures risk factors appeared, anticonvulsant agents must be applied
Approved recommendations							
Whenever volume depletion or hypotension appeared, ketamine should be applied. Additionally, when there was an absence of adrenal insufficiency, etomidate must be considered.	Prevent from hyperventilation condition when partial pressure of carbon dioxide lower than 300 mmHg	The recommended amount of hypertonic saline is 3%	The body temperature is recommended to maintain in normal condition	The level of sugar in the blood is recommended to be normal	The clinical effectiveness of conducting PECARN is to help clinical specialists in making emergency decision or brain imaging	There not any proved documents on ordinary application of monitoring for controlling the pressure inside the skull	There is not any proved documents for ordinary application of preventive anticonvulsant agents



easily.<sup>67</sup> Similar to whole findings above, recently the some studies published also is considered these points mentioned.<sup>68-75</sup> Finally, various scopes of management of pediatric TBI are briefly mentioned in Table 3.

## Conclusions

Performing the most appropriate health care procedures for management of pediatric TBI needs a multidisciplinary approach in any management phase. After the primary assessment, quick diagnosis, precise multimodality monitoring and appropriate management of increment of pressure around the brain are required for minimizing or preventing pediatric TBI. Clinical practice guidelines are useful tools for proper management of pediatric TBI with the potent potential of informing the progression of care systems of happened trauma with the capability of improving the health care delivery quality. Through setting the proper guidelines for obtaining the most effective outcomes for this particular population, a higher improvement in the quality of management of clinical practice guidelines of pediatric TBI will be achieved. Additionally, by focusing on progression process of the most effective guidelines, the opportunity for training and building more skillfulness specialists in administering clinical practice guidelines would be created. On the other hand, creating more appropriate standardized strategies based on patient's characteristic, common clinical symptoms, presence of increased pressure inside the skull, along with available healthcare resource limitations, could enable clinicians of emergency medicine department and related critical care physicians for proper management of pediatric TBI. In this regard, novel treatment options should be investigated to achieve outcomes that are more effective.

## List of acronyms

BSF- Basal skull fracture  
CSF- Cerebrospinal fluid  
CT -Computed tomography  
DWI -Diffusion-weighted imaging  
GIM -Global Index Medicus  
MRI -Magnetic resonance imaging  
NMR- Nuclear magnetic resonance  
PGCS- Pediatric Glasgow Coma Score  
SWI- Susceptibility weighted imaging,  
TBI- traumatic brain injury  
TSDH- Traumatic subdural hematoma

## Authors contributions

All authors played a substantial role in the conception and/or study design, drafting and finalizing of the manuscript. They agree for all aspects of accuracy and integrity of the work.

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## Conflict of Interest

The authors declare they have no financial, personal, or other conflicts of interest.

## Ethical Publication Statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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